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CHANGES IN THE CLIMATE OF NORTH AMERICA.

WHEN the first Romans visited the coasts of Great Britain they were amazed at the violence of the tidal waves and their evident independence of atmospheric disturbances. "Portentous billows suddenly assail the shore," says Pliny, "and often during a perfect calm." With a similar degree of wonder and dismay the first colonists of the New World must have experienced the vicissitudes of the North American climate. Emigrants who attempted to settle in the latitude of southern France returned with frozen noses. In Ohio, where the thermometer sinks to 25° below zero, Taine's Farmer Graindorge drives his hogs through "palm-groves resounding with the screams of countless parrots." Palms thrive pretty well at Genoa, four hundred miles further north than Cincinnati. Fishing-smacks coasting along the south shore of Lake Superior in May often encounter ice-floes a hundred feet long, and thick enough to endanger the timbers of a steamer. To the natives of southern Europe there is something abnormal in this combination of high icebergs and low latitudes. A Spanish surveyor whom I met in Colorado last winter was so puzzled by the eccentricities of the weather that he suspected a mistake in the computed altitude of the country. Denver, he thought, must be at least ten thousand feet above the level of the sea.

And yet a North American Indian visiting Spain in mid-summer would have far better reasons for complaining about the grievances of an unnatural climate. The truth is, that the meteorological conditions of our country prevailed under nearly the same latitudes of the Old World before its climate was modified by the progress of agriculture and the clearing of vast woodlands, and it is not less certain that the action of similar causes has begun to change the climate of the United

States. The calorific influence of the Gulf Stream is generally overrated. When both Europe and North America were covered with continuous forests, the east shores of the Atlantic had the advantage of milder winters, but their summers were neither warmer nor dryer than ours. On the contrary, the seven sea-girt peninsulas of Europe enjoyed the benefits of a maritime climate; droughts were so rare that their occasional occurrence was considered a portent; deserts, in the present sense of the word, were confined to Araby and central Africa. Northern Africa not only produced food enough for her own teeming population, but was the granary of the *Orbis Romanus*, an inexhaustible store-house of oil, wine, and wheat. Where now the oven-breath of the Harmattan sears the naked hills of Tunis, orchards, alternating with shady forests, once covered an extent of country which, in spite of frequent hunting expeditions, was to its Roman conquerors still a sylvan *terra incognita*, and in no sense an undesirable country, judging from the subsequent fierce contests for its possession. In eastern Algiers, the ancient Cyrenaica, De Baudin recorded 128° in the shade for eighteen successive days. The climate of the whole country must have become about thirty degrees warmer; that of southern and central Europe at least twenty degrees. In the time of Xenophon, Greece had harder winters than modern Dalmatia; on the expedition against Corcyra, Socrates marched barefoot through the deep snow to silence the effeminate complaints of his young companions. Cyrus the Great used to pass seven months of every year at Babylon in the Euphrates valley, a "region of perpetual spring," as his biographer calls it, in the same valley where the dog-star now seems to rage perennially. Several poets mention the "snowy summit of Mount Soraete," a south Italian mountain of very moderate elevation. Tacitus speaks of frozen lakes in northern Italy, and his description of the German woodlands, "horrid with frost," would have answered the present state of affairs in northern Canada. Asia Minor has become the epitome of a dying continent. In Spain the agricultural value of the lowlands, which once attracted the Visigoths from their Danubian homes, has been reduced by more than eighty per cent. From Suez to Gibraltar the coast lands of the Mediterranean have wasted away in a decline, which seems to be the ultimate fate of all civilized countries. The burning drift-sand of the desert is perhaps the Wad-el-Har of

the Koran, the fire-sea, which is destined to engulf all things at the end of time. Planets die by desiccation.

And there is no doubt that the hectic glow of that malady begins to be felt in the lands of the western hemisphere. Our civilization is but of yesterday, compared with that of the Mediterranean nations; but ours is an age of rapid transits. The ancients traveled the same road, but at a slower pace. They, too, thought to improve their lands by the wholesale destruction of their woods; like our Southern planters, they saw the direct benefits of agriculture, and ignored the climatic influence of forest-vegetation; but they had no steam-saws, no wood-devouring railroads, and even cottages were mostly built of stone. In two centuries the lumbermen of the United States have killed as many trees as the inhabitants of southern Europe felled in the two thousand years between the foundation of Rome and the conquest of Granada. The same causes begin to produce the same effect. Only six months ago the Boston papers called attention to the gradual shrinking of the water-courses which once turned the mill-wheels of the New England manufacturing towns, and gave a long list of factories which had once a surplus of water-power, but have now to depend on steam. Many tributary brooks of the Connecticut River not only shrink, but disappear in midsummer. In southern Virginia, and the midland counties of North Carolina, Georgia, and Alabama, the owner of a perennial spring has become an object of envy. The first settlers of the "Blue Grass Region" would not recognize it in the present colors of its sere and dusty summer dress. Next to the mesquite grass of the Texas table-lands, cotton can perhaps stand more dry weather than any other plant of the temperate zone, and the staple industry of the South has managed to hold its own; but even cotton-planters admit, with some uneasiness, that the droughts of the last ten years are unprecedented, and that the average dryness of the summer season is steadily increasing*. Toward the end of summer the citizens of Tuscaloosa, Ala., and the neighboring towns are often worried by the temperature of a home-made *harmattan*,—a dry south-east

* The drought of 1881 seemed unparalleled, but in several of the Southern States it was surpassed by that of last summer, and the Alabama and several North-Georgian rivers were lower than they were ever known to be since their valleys were settled by European colonists. At Lula, Georgia, twenty miles east of Gainesville, the drought lasted from May 22d to November 3d.

wind that makes the hills hazy and the streets dusty-hot. It comes from the interior of the "cotton counties," where thousands of old fields have been worn out and abandoned, till the weather has furrowed them with deep, arid gullies.

The desiccation of a de-forested country always begins in the lowlands. When the vegas of southern Spain had become dismal sand-fields, the Sierras were still green with their primeval forests; now they are as barren as the plains. Our floor is afire: shall we stand by and trust the safety of our house to the intervention of a miraculous Providence? Since the beginning of our chronological era, the nations of the Caucasian and Semitic races have probably spent a thousand billion dollars, and written a million books, to prepare for the future in *Niffelheim*, the cloudland of their various hyperphysics. Would it not be as well to bestow a little thought on the less unknowable future of our own earth? If we continue to tread the beaten road, we can no longer plead ignorance of its goal. Whenever a progressive phenomenon is traced to a known cause, the veil of the future becomes transparent: the fate of Asia Minor is a lesson which has been repeated too often to be misunderstood, and the impending changes in the physical geography of our continent can be predicted from unmistakable analogies. In the Gila valley the improvidence of a prehistoric race has already begun to Africanize our compact continent, and if the same agencies continue to modify the climate of the Atlantic slope, our cotton states will, in fifty years from now, be reduced to the necessity of raising their crops by the aid of irrigation. The locust will ravage the plains of the Gulf coast. Agriculture will invade the highland valleys of the Alleghanies. The soil of the mountain-slopes, stripped of their forests, will be washed away by winter rains and thawing snows. Rivers will shrink to brooks in summer, but flood their valleys in spring; Louisiana and southern Arkansas will be inundated as regularly as Egypt; and at the mouth of the Mississippi the deposits of river-sediment will keep a host of dredge-boats busy. Droughts will depopulate the sandy central plateau of the Gulf states. General Hazen has proved that an enormous area of the great North-west will repay the toil of tillage only in exceptional years, and that its average summer climate always touches the limits of withering aridity. After the clearing of the few remaining areas of woodland, the climate will pass those limits, and in the "granary

of the West," too, agriculture will be confined to the irrigable valleys of the large streams. Those valleys, the river-estuaries and the foothill-regions of the higher mountain ranges, will be studded with large cities. Before the middle of the next century the present territory of the United States will have two hundred million inhabitants. As in England, the abundance of coal and iron, and the enormously increased price of good farming-land will drive thousands of farmers into the factory towns; but the evils of industrial over-production will, in turn, stimulate the search for new homes, till the nooks of the remotest highland valleys have shared the fate of the wasted plains.

Then, and perhaps not till then, will come the reaction. Confronted with the alternative of reform or death by starvation, man, the destroyer, will become a reconstructor, and redeem the earth by forest-culture. A time will come when the great secret of this planet, the genesis of the desert, almost equivalent to the exegesis of evil, will become a familiar fact. That time will form a turning-point in the physical history of our earth. At first, though, the urgency of his direct needs will oblige the tree-planter to discriminate in favor of fruit-trees.

The starving farmer of the Old World takes refuge in emigration; but when the exhaustion of the West American and Australian soil shall leave us no New World to fall back upon, when all the arable land from Maine to California shall produce its utmost, and yet insufficient crops, the significance of the *hic aut nusquam* will be brought home to the nonplussed cultivator, and necessity will enforce the earth-transforming rule that in an over-populated land of limited agricultural resources herbs and cereals must give way to arboreal plants. An acre of ground planted with bananas will feed as many persons as thirty* acres of the best potatoes or twenty-five acres of wheat. In many parts of southern Europe the chestnut is the bread-plant. Of a most prolific variety which is cultivated in the highlands of the Apennines, and would thrive as far north as Connecticut, a single tree often produces several thousand sweet and mealy half-ounce nuts, which the Italians grind like corn, and use for various palatable farinaceous preparations, in nutritive value far superior to the potato and rye-bread diet of their northern neighbors. Xenophon mentions the "chestnut-fed

* Humboldt says even forty-four, but the improved methods of culture have since developed more prolific varieties, both of the sweet and "Irish" potato.

children" of the Bythinian mountaineers,—“boys as broad as they were long.” Olive-trees live six centuries, and after the tenth year an olive-garden produces fourteen times as much oil as the same area of any annual plant. The same holds good of the northern beech and the arborescent hazelnut. The prolific Turkish sugar-plum thrives on soil where neither sugar-cane nor sorghum would grow. *Baum-wolle*, the German word for cotton, means literally *tree-wool*, and several tropical trees, especially the *bombacea*, could furnish that material in every desired quantity. Bombax-wool is almost as fine and strong as silk, and the length of the fiber might be improved by cultivation.

Extensive tree-plantations, though at first perhaps dependent on irrigation, would soon begin to generate their own rain, and modify the climate of the surrounding country. In a previous paper I have pointed out the physiological *rationale* of that influence; its practical results can be seen in the replanted coast woods of western France and in all highlands that have preserved their mountain forests in the midst of a treeless region, as in the Caucasus, in the Black Hills of Dakota, and the forest districts of the southern Balkan. And arboriculture would improve the social as well as the physical climate. The same plantations that will restore the moisture of our atmosphere lessen the toil of the husbandman. Cereals and hundreds of herbs have to be replanted, recultivated, and refertilized year after year, and nearly all the products of that infinite labor could be derived from trees that not only take care of themselves, but improve with every season and enrich the soil by the fertilizing influence of their falling leaves.

Orchards, therefore, will probably open the campaign against the desert, and forest trees will be added only to utilize the soil of the northern mountain regions. It is doubtful if the projects of the forestry movement will be seconded by our country population till the advantages of tree-culture shall be brought home to them by the logic of absolute necessity. But in one respect, at least, the folly of forest destruction has already begun to demonstrate its perils with sufficient impressiveness to insure the popularity of remedial measures. I refer to the danger of winter floods. The Emperor Julian, who commanded the legions of Gaul for a number of years, states that the valley of the Seine was at that time entirely exempt from inundations. “*Qualis aestate, talis esse solet hieme*,” he adds, in speaking of a river whose level varies now more than thirty feet! The same in southern

France, in Italy, and Spain. Rivers which almost disappear in the dry season swell to torrents in winter-time; and hence the baneful fallacy of the meteorologists who deny that forests exercise any appreciable effect on precipitation. The total annual rain-fall may not vary; the Rhone, the Po, and the Ebro may still carry the same amount of water to the sea; but formerly the forest equalized the drainage of that water, where its absence now decreases the rains of the summer season and increases their destructive effect in early spring, especially in mountainous countries. Twenty years ago, De Bonville, prefect of the Lower Alps, addressed to the government a memorandum in which he describes the appearance of the upper mountain valleys after the loss of their forests:

“There is no doubt that the vegetable mold of the Alps, swept off by the increasing violence of that curse of the mountains, the torrents, is daily diminishing with fearful rapidity. All our Alps are wholly, or in large proportion, bared of wood. Their soil, scorched by the sun of Provence, cut up by the hoofs of the sheep, which, not finding on the surface the grass they require for their sustenance, scratch the ground in search of roots to satisfy their hunger,—is periodically washed and carried off by melting snows and rain-storms.”

The junction of several swollen torrents has repeatedly raised the rivers of southern Europe to ten times their usual height, and produced devastation which Blanqui compares to the effects of an earthquake: deserted villages, mountainous heaps of uprooted trees and *débris*, fields covered with square leagues of scattered gravel. The valley-dwellers of eastern North America have already become familiar with similar scenes. But while the Rhone drains only fourteen thousand square miles of highlands, the Ohio is swelled by the drainage of 60,000 square miles of mountain countries, in a large portion of which spring rains are more frequent than in the southern Alps. In Pennsylvania, Kentucky, West Virginia, and Tennessee, the lumber trade increases more rapidly than any other branch of industry, and, in the river valleys, the steadily increasing maxima of high-water marks, as well as the devastating floods of 1882, 1883, and the present year,* are therefore

* The total damage of the flood of 1882 has been estimated at \$12,000,000 in Ohio and Indiana; of that of 1883 at \$22,000,000 in Ohio, \$8,000,000 in Indiana, and \$6,500,000 in western Kentucky.

only playful allusions to the probabilities of the next twenty years.

But while droughts can be counteracted only by a widespread system of coöperative tree-culture, spring floods admit of more local remedies. With rare exceptions they originate in mountain countries, where two causes combine to increase the evil effects of forest destruction: the steepness of the drainage slopes, which pour down the floods before any considerable portion can be absorbed by the soil, and the effects of premature spring seasons,* which swell the torrents with the thawing snows of the upland regions. Arboreal vegetation obviates those perils by absorbing, or at least retarding, the drainage even of the steepest slopes, to a degree which almost exempts from inundations the river valleys of densely wooded hill countries; and the only radical remedy would, therefore, be to protect or replant the forests bordering the valleys of all the upper water-courses. Mountain land is so cheap that extensive tracts could be re-bought by the Government at nominal prices; and in the upper Alleghanies there are mountain slopes that could be intrusted to their natural safeguards—their steepness and their rockiness. Still, here and there a local demand for fuel has overcome such obstacles. High up in the alpine valleys of Polk County, Tennessee, a single establishment—the furnace of the Ducktown copper mine—has devoured the trees of a hundred hills. The Chesapeake and Ohio Railroad has done the same for the mountains of West Virginia, and the Virginia and Tennessee Railroad for the valley of the upper James River.

In such valleys, and especially where the nature of the soil threatens to delay the growth of young trees, the replanting of the forest should be supplemented by precautions against immediate dangers. Nature has given us a hint, which the Spanish Moors acted upon in the construction of the vast *alberkets*, or river reservoirs, which regulated the water supply

* The flood of 1883 was caused by premature thaws in the mountains of West Virginia and Pennsylvania. When Pennsylvania was first settled, winters like the two last would have been considered miraculous; the heavy snow-fall in the north counties used to blockade the overland road to New York every year. The old settlers of northern Georgia remember a time when the Toccoa River used to “freeze solid” at least every other year; while during the last fifteen years it froze only twice—in February, 1877, and in December, 1880.

of the South Spanish vegas. Wherever a river expands into a chain of lakes we find that such lakes serve not only as reserve basins in all but the driest seasons, but also protect the valleys of their effluent streams against the floods of the upper tributaries. A rain that would cause the overflow of a narrow mountain stream in a single day might continue for weeks without effecting an appreciable change in the level of a large lake. A smaller lake, or even a mere *bahia*, as the Spanish-Americans call the expansions of their coast rivers, would at least compromise matters by distributing the deluge over a basin, where evaporation, and especially the water-absorbing alluvium of an extended shore-line, would diminish its volume, while the slower rise of the expansive water-level would retard that of the effluent stream. No rains have ever flooded the great lake-river of our Canadian frontier. Violent north-east storms have now and then "backed" the waters of Lake Erie till the Niagara River sank visibly below its normal level,—once so much, indeed, as to expose the naked rocks of the Horse-shoe Fall,—and the sudden bursting of an ice-gorge might produce the opposite effect; but there is no case on record that a wet spring, or the sudden thawing of the snow in the upper lake region, had endangered the river suburbs of Buffalo. Between Lake Lemane and the hills of St. Rambert the level of the Rhone varies only a few feet; below its confluence with the Ardèche and other torrents of the Cevennes, its valley is subject to inundations which, in the words of Blanqui, have repeatedly done more mischief than an invading army of vandals could have perpetrated in the same time.

In the Ohio valley, as well as in southern France, the worst floods were always caused by the simultaneous swelling of mountain streams, which rose in a few hours to a height of twenty or thirty* feet above their normal level, but subsided as rapidly; so that a short delay of their torrents would, in the lower valleys, have made all the implied difference of a full and an overflowing river. In the lowlands, a river reservoir of sufficient dimensions would involve expenses too disproportionate, even for such a purpose; but in the mountains, where the hills themselves would form two sides of the

* In 1827, the Chassezac, a tributary of the Ardèche, rose sixty feet in less than two hours.—Montluisant, "*Annales des Ponts et Chaussées*," p. 112.

basin walls, it would be easy to find points where the wildest torrent could be tamed by the construction of a dike across the gate of a narrow mountain gap, and where the expansion of the valley above the defile would form a basin of sufficient size to retain the floods of the worst rain-storm. For it would be rarely necessary to check the drainage for more than a single day. We have seen that the chief peril could be averted by preventing the simultaneous influx of several swollen highland streams, and by a system of telegraphic communication between the several reservoirs the discharge of their water could be regulated in a way to obviate such conjunctions. Besides, rain weather wanders; the observations of our signal stations have shown that rain-storms often move from Maine to Mexico, and that the degree of their violence is nearly always in inverse ratio to the length of their persistence at a given point. In exceptional cases the demand upon the limited capacity of a safety basin can be diminished by digging horizontal furrows along the upper hill slopes. The volume of the water thus retained will be reduced by infiltration, and the ditches can be utilized for irrigating purposes. In 1859 the French Government adopted this plan in the Cevennes, where the gradual erosion of the mountain slopes threatened to destroy the last pasture-grounds of the highlands. The reservoirs themselves might likewise be used for collateral purposes,—mill weirs, fish tanks, etc., and in dry seasons for the irrigation of the lower valleys.

The chief objection to the construction of artificial mountain lakes would be the more than usual degree of the danger to which all large water-reservoirs expose the country below their sluices. Even in the lowlands the bursting of such tanks has demolished whole villages, and the effects of a water-avalanche from the highlands would rival the havoc of a cloud-burst. Infiltration, followed by a hard frost, or even the pressure of the accumulated waters, might initiate such an event. Violent rains would reënforce the torrents of the upper valleys by the descent of rolling boulders, which might damage, if not destroy, the bulwarks of the storage-basin. To obviate such dangers, the inner walls of the basin would have to be lined with cemented masonry, and at dangerous points with the bracket-fitted stone blocks that resist the breakers of Eddystone. The primary expense of such a work would be still further increased by the necessity of temporarily diverting the channel of the torrent.

But such objections should be outweighed by another consideration. The damage of winter floods is not limited to their direct results. A mountain torrent not only spreads havoc over the fields of its own banks, but has also a baneful tendency to shoal the channel of the valley rivers, thus making them more liable to overflow their banks. Castellani (*Dell' Influenza delle Selve*, I. p. 58) says that formerly it required a week's rain to cause an inundation of the Po, while nowadays a single rainy day is often sufficient to produce the same result. The amount of gravel which a single small river, the Mella, swept down during the inundation of 1850, has been estimated at 108,000,000 cubic yards, which almost obliterated the bed of its own channel, as well as that of the upper Oglio. (*Delle Inondazioni del Mella, nella notte del 14 al 15 Agosto, 1850.*) From the progressive changes in the coast line of the Adriatic, it has been computed that since the beginning of our chronological era the Po and its affluents have thus transported not less than three hundred thousand million cubic yards of earth and gravel! Professor G. P. March ("Man and Nature," pp. 258, 259) quotes several still higher estimates. As a natural consequence, the bed of such rivers rises higher and higher, till the reconstruction of the dikes involves an almost insupportable expense. The dams of the Fersina had to be raised above the city walls, and at last even above the housetops of Trent, till now the river seems to run along the ridge of a long-stretched chain of artificial hills. (Streffler, *Ueber die Wildbäche*, p. 7.) The bursting of such dikes is a national calamity. The floods that visited France and Germany last year caused more permanent damage than the Franco-Prussian war. The worst havoc resulted in both countries from *crévasses*, as our Creoles call the dike-ruptures of the Lower Mississippi.

And yet the same risk will soon have to be incurred in many valley regions of our Central States. The river counties of Indiana and Kentucky have already begun to adopt that method of protecting their fields against the inundations of the Ohio. Before the end of this century the increased frequency of winter floods and the augmented value of lands in the valleys of the Ohio, the Cumberland, the Susquehanna, the Potomac, and the Delaware, will stimulate the demand for "levees" beyond the boldest hopes of our present Congressional jobbers. The present high water-marks of these rivers would imply no in-

superable difficulties, even in the plains of western Kentucky, where neither hills nor dunes facilitate the labor of the diikers. The maximum of 1884 may not soon be exceeded. But it would alter the case if the river-bed itself should change its level. If the mountain streams of the Alleghanies continue to encroach upon their banks, their *detritus* will soon begin to shoal the valley rivers, their mud deluges will turn the bottom-lands into malarial fens, and the settlers of the Ohio valley will share the experience of Castellani's countrymen, whose gravel-choked rivers are apt to overflow upon the slightest provocation. In other words, unless preventive measures are adopted in time, the frequency of winter floods will soon increase, as well as their destructiveness.

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